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Endemic and rare Collembola distribution in High Endemism Areas of South Portugal: A case study

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Abstract

We studied the Collembola Populations from High Endemism Areas (HEA) in the Algarve (Portugal) in order to look for endemic or rare species and obtain information on the origin and maintenance of endemism in this region. Here, five well defined ecological areas have revealed good examples of endemicity mainly concerning Phanerogames but also several Arthropod groups. The overall analysis revealed three groups of sites among the studied areas: (a) Serra de Monchique, (b) coastal 'wet' biotopes (salt-marshes and dunes) and (c) other 'dry' coastal and inland sites (Sagres, Pinewood and Barrocal sites). In these areas we have found 15 endemic Collembolan species (8 species to Portugal and 7 to Iberian Peninsula) and 23 species not yet referred to Portugal (20 species) or to the Iberian Peninsula (3 species), which contribute to enhance the real biological value of these sites in terms of biodiversity conservation. © Elsevier, Paris

Keywords: Collembola, High Endemism Areas, endemic species, Algarve, South Portugal.

Analyse de la distribution des espèces endémiques ou rares de Collemboles dans des « High Endemism Areas » du Sud du Portugal, Algarve.

Résumé

Les auteurs ont étudié des populations de Collemboles provenant de « High Endemism Areas » (HEA) dans l'Algarve (Portugal) afin de chercher des espèces endémiques ou rares et tâcher d'obtenir des informations sur l'origine et le maintien de l'endémisme dans cette région. Cinq aires bien délimitées du point de vue écologique ont révélé de bons exemples d'endémisme, principalement en ce qui concerne les Phanérogames et plusieurs groupes d'Arthropodes. L'analyse globale des résultats révèle une séparation nette de trois groupes de biotopes parmi les aires étudiées : les biotopes de la Serra de Monchique, les biotopes « humides » du littoral (marais et dunes) et les autres biotopes « secs » du littoral plus les biotopes de l'intérieur (Sagres, bois de pins, Barrocal 94 et Barrocal 96). Dans ces biotopes nous avons trouvé quinze espèces endémiques de Collemboles (huit espèces pour le Portugal et sept pour la Péninsule ibérique) et vingt-trois espèces qui n'étaient pas encore mentionnées pour notre pays (vingt espèces) ou pour la Péninsule ibérique (trois espèces), ce qui souligne la valeur biologique réelle de ces aires du point de vue de la conservation de la biodiversité. © Elsevier, Paris

Mots-clés : Collemboles, « High Endemism Areas », espèces endémiques, Sud du Portugal, Algarve.

INTRODUCTION

Biodiversity conservation is of growing concern among environmental scientists and public opinion. Conservation of rare insect genetic material is essential and particular attention should be given to those areas where endemism is high. It is also of general value to conserve typical species and sites as well as rare endemics (Samways, 1995).

Endemic biota, which represent the most valuable and vulnerable elements of the fauna from a conservation perspective, are not considered of prime importance in nature conservation (Deharveng, 1996):

the centres of endemism located in Western Europe are not completely known.

Algarve, the southernmost province of Portugal, is a special zone of biodiversity in the Iberian Peninsula, with several species of plants and animals endemic to this region. Here, five well defined ecological areas have revealed good examples of endemicity chiefly concerning Phanerogames (Rocha Afonso, 1991) but also Thysanura (Mendes, 1985, 1992), Coleoptera Cicindelidae (Horn, 1937; Serrano, 1988, 1995) and Homoptera Cicadoidea Tibicinidae (Boulard, 1982; Quartau, 1995).

We analysed the Collembola populations from these areas in order to look for endemic or rare species and obtain information regarding the origin and maintenance of endemism in this region. Collembola are, together with the Oribatid mites, the most abundant and diversified arthropods in soils, providing an efficient tool for biodiversity assessment in soil habitats (Deharveng, 1996).

This study revealed a few rare or endemic species, in addition to species not yet cited to Portugal and will contribute to increase the real biological value of this region.

MATERIALS AND METHODS

Study sites

Five areas were sampled, representing the major landscape units in the Algarve province, and chosen by the presence of several species of plants and insects endemic to this region (*fig.* 1). In the Serra de Monchique, Barrocal and Ria Formosa we considered several biotopes (some sampled in different sites),

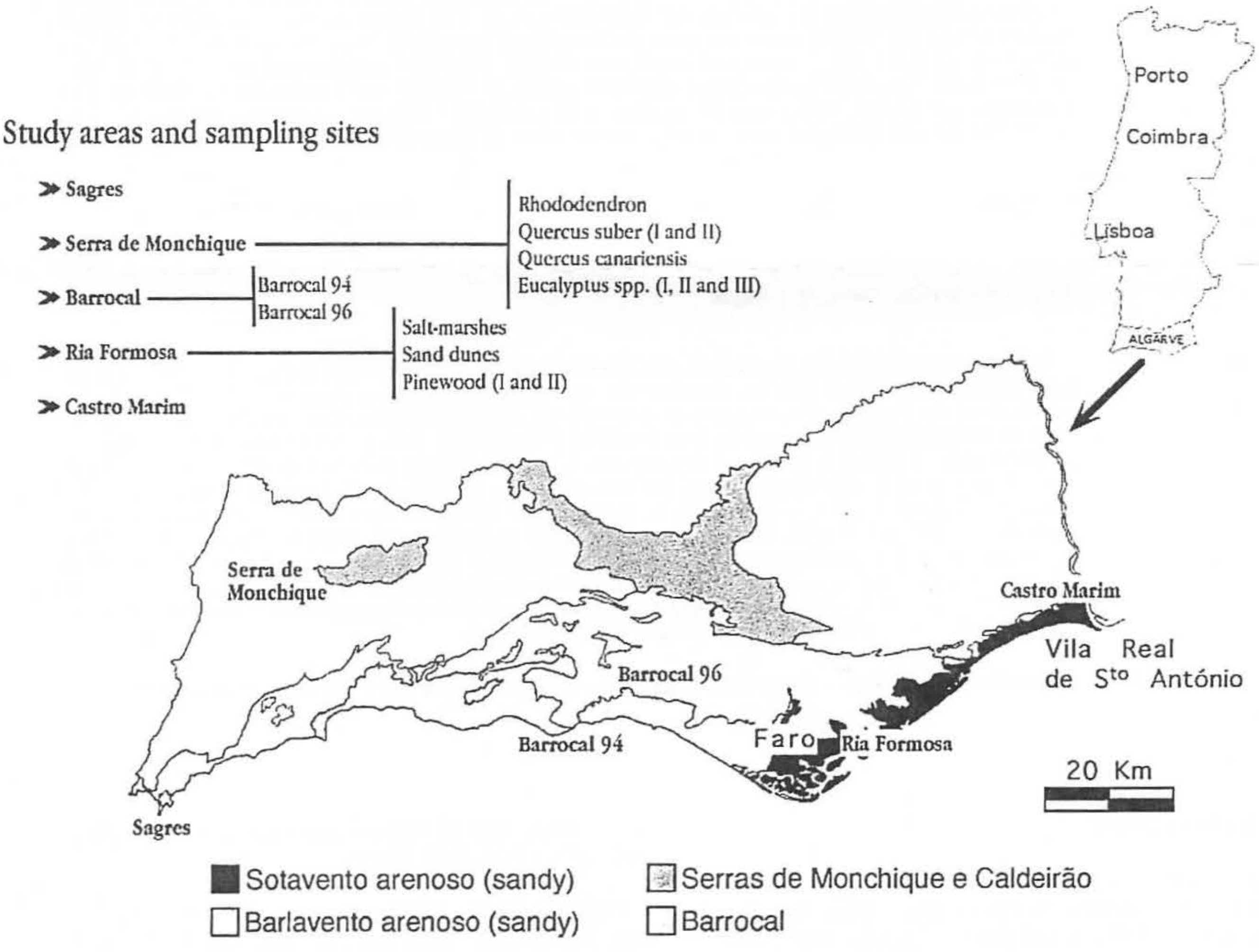

Figure 1. – High Endemism Areas (HEA) and sampling sites in the Algarve.

whereas in the Península de Sagres and Castro Marim only one biotope was considered[1]. Site botanical characterization was based on plant identification during visits to the field and in Rocha Afonso (1991).

Península de Sagres: [Sagres] a calcareous dolomitic region in the south-west extreme of Algarve, with cliffs ranging from 40 m high (Ponta de Sagres) to 70 m high (Cabo de S. Vicente). The area is covered by shrub and herbaceous layers dominated by *Cistus ladanifer* L., *Thymus camphoratus* Hoffmanns & Link, an endemic species in southwestern Algarve, and *Armeria pungens* (Link) Hoffmanns & Link.

Serra de Monchique: the upper half of this mountain is predominantly syenitic, including Foia (902 m high), whereas the lower zone has a schistose nature. In this massif, there are quite rare species of Phanerogames such as *Rhododendron ponticum* L. ssp. *baeticum* (Boiss. & Reuter) Hand.- Mazz.('Iberian Rose Bay'), a relictual endemic restricted to a few sites of Southern Iberian Peninsula. Another important species above 400 m of altitude is the Monchique oak, *Quercus canariensis* Willd., which presents a very restricted occurrence both in Portugal and in Spain, Serra de Monchique being its exclusive area in Portugal.

The sampled biotopes were: *Rhododendron ponticum baeticum* [Rhododendron], *Quercus canariensis* [Q. canariensis], *Quercus suber* [Q. suber I and II] and *Eucalyptus* sp. [Eucalyptus I, II and III]. Almost all sites (with the exception of Q. suber II) had shrub and herbaceous layers composed mainly of *Pteridium aquilinum* (L.) Kuhn, *Cistus* spp., *Erica* spp. and *Viburnum tinus* L. (on oak and eucalyptus sites). All eucalyptus sites were in second rotation and with a large accumulation of leaves and bark on the soil surface.

Barrocal corresponds to a calcareous platform, bordered at the southern littoral by the sandy zone of the Barlavento and the Sotavento. Samples were taken at Carvoeiro, near Farol de Alfanzina, and at a place located between the villages of Alte and Salir (see *fig.* 1):

• In the first biotope [Barrocal 94] the shrub and herbaceous layers were composed mainly of *Pistacia lentiscus* L. and *Chamaerops humilis* L., the dwarf fan palm, found frequently in the Barrocal.

• In the second biotope [Barrocal 96] the samples were taken mainly around *Ceratonia siliqua* L. (carob tree), one of the most characteristic trees of the Mediterranean region, with a rich shrub and herbaceous layer of *Pistacia lentiscus* L., *Daphne gnidium* L., *Cistus albidus* L., *C. monspeliensis* L. and *Phlomis purpurea* L., which in the Algarve is found only in the Barrocal.

Parque Natural da Ria Formosa is a protected coastal area in the south-east of the Algarve, and is partially covered by sand dunes, salt-marshes and pine forest. Samples were taken at Quinta de Marim in May 1995 and in March 1996.

• In salt-marshes [Salt-marshes] the vegetation was composed of *Spartina maritima*, *Sarcoccornia perennis* ssp. *perennis, Halimione portulacoides* (L.) Aellen, *Mesembryanthemum nodiflorum* L. and *Limoniastrum monopetalum* (L.) Boiss.

• Sand dunes [Dunes] had an abundant and diverse vegetation composed of *Spartina maritima* (Curtis) Fernald, *Juncus maritimus* Lam., *Suaeda albescens* Lázaro-Ibiza, *Suaeda vera* J. F. Gmelin, *Sarcoccornia perennis* (Mill.) A. J. Scott ssp. *perennis*, *Paronychia argentea* Lam., *Cistanche phelypaea* (L.) P. Coutinho and *Dittrichia viscosa* (L.) W. Greuter ssp. *revoluta* (Hoffmanns & Link) P. Silva & Tutin, an endemic of sandy places in Algarve.

• In pine stands, constituted by *Pinus pinea* L. and *P. pinaster* Aiton, two sites were sampled: (1) *Pinus* I [Pinewood I] had a shrub and herbaceous layer composed chiefly of *Euphorbia segetalis* L., *Cistus salvifolius* L., *Arum italicum* Miller, *Oxalis pes-caprae* L., *Urginea maritima* (L.) Baker and *Halimium halimifolium* (L.) Willk., which is very common on littoral sands or in sandy places not far from the sea, both in Barlavento and in Sotavento; (2) in *Pinus* II [Pinewood II] the vegetation was less abundant and composed mainly of *Linaria spartea* (L.) Hoffgg. & Link, *Linum bienne* Miller and *Cistus salvifolius* L.

Reserva Natural do Sapal de Castro Marim: this protected area of salt-marshes is located in the south-east corner of the Algarve. Sampling in this biotope was carried out in May 1995 [C. Marim 95] and in March 1996 [C. Marim 96]. During this last sampling period, the vegetation cover was abundant and diverse, with a large number of species not characteristic of this type of habitat. It was composed mainly of *Chamaemelum fuscatum* (Brot.) Vasc., *Halimione portulacoides* (L.) Aellen, *Oxalis pes-caprae* L., *Sarcoccornia perennis* (Mill.) A. J. Scott. ssp. *alpini* (Lag.) Castr., *Plantago coronopus* L., *Cistus monspeliensis* L., *Lythrum junceum* Banks & Solander, *Juncus buffonius* L., *Triglochin maritima* L., *Amophila arenaria* (L.) Link ssp. *arundinacea* H. Lindb. and *Limoniastrum monopetalum* (L.) Boiss.

Sampling and soil analysis

Sampling was carried out on several occasions between 1994 and 1996. In each biotope several points (7-29) were randomly selected and at each point two 250 cm^3 samples were taken (one in the organic horizon and another in the mineral horizon); (surface area $\leq$ 100 cm^2). When litter was absent, we took only one sample of 500 cm^3.

After the faunal extraction (Berlese-Tullgren funnels, 1 week), the air-dried samples were characterized: pH was measured in water (1/6 v:v) at

1. Designation of the biotopes and sites sampled in each of the five areas (names used in tables and figures) appear in brackets.

20°C; water content was measured according to Dewis & Freitas (1984) and expressed in terms of percentage of water in relation to dry mass at 105°C; organic matter content was expressed as Ash Free Dry Weight; carbon and nitrogen contents were determined, respectively, by Anne's and Kjeldahl's methods (Dewis & Freitas, 1984). Physical and chemical characterization is represented in *table* 1. Due to non significant differences among measured parameters at the different sites of Pinewood, C. Marim, Q. suber and Eucalyptus, the values were pooled.

Data analysis

Differences in community composition of each biotope were evaluated using both diversity and multivariate analysis. Prior to analysis, in order to establish comparisons between sites, data were pooled on those points where two samples of 250 cm^3 were taken, making an equal sample size of 500 cm^3 for all sites.

In the first level of analysis, the indices of diversity (Shannon-Weaver), evenness and species richness (Margalef) were calculated for each site (Magurran, 1991). In the second level of data treatment, a Correspondence Analysis (CA) was applied to the global data matrix (16 sites vs. 174 taxa). Prior to the analysis, and in order to correct for differences in the number of samples taken at each site, the values were expressed in terms of mean number of individuals per volume unit.

RESULTS

From the chemical data, a noticeable difference is observed between coastal and inland habitats in terms of water, organic matter and nutrient contents (*table* 1). This is particularly evident in the mineral horizon and can be explained by the structure and composition of the vegetation cover and the extent of the biological processes on soil formation. In fact, inland habitats (Serra de Monchique and Barrocal) are woodlands with herbaceous, shrub and arboreous layers, with litter accumulation on the soil surface, whereas most of the coastal habitats only present herbaceous and shrub layers standing in a poor sandy or rocky substrate. The fact that some of these sites are periodically flooded (with continuous removal of plant debris) may also contribute to the poor incorporation of organic matter into the soil.

In terms of Collembola, a total of 30 203 specimens, belonging to 174 taxa, were identified in the five sampling areas.

Rhododendron had the highest collembola abundance of all sites, with a mean number of 504.1 individuals per sampling unit (*table* 2). There was a decreasing gradient in terms of abundance from the other inland biotopes to the coastal sites (C. Marim 95 and 96, Salt-Marshes and even Sagres). The mean number of taxa followed a similar pattern. This gradient seems to be related to soil physical and chemical characteristics (*table* 1); a higher number of individuals and taxa per sample occurred on sites with higher values of soil water, organic matter, carbon and nitrogen contents in the mineral horizon. This is consistent with published information relating higher abundance and species richness of Collembola with humid environments and sites with higher organic matter content (Rusek, 1989).

A different gradient in species diversity was observed. Although Q. canariensis site had the highest value, the coastal biotopes (Sagres and sites from Ria Formosa) had, in general, higher values of species diversity. The exception is the salt-marsh biotope from C. Marim; the low diversity values obtained

Table 1. – Physical and chemical characteristics of soil in the sampling areas (average ± SD).

		Ria Formosa					Serra de Monchique			
	Sagres	Salt Marshes	Dunes	Pinewood	C.Marim	Barrocal	Q. suber	Q. canariensis	Rhododendron	Eucalyptus
Organic horiz.										
pH	7.01±0.91					6.73±0.24	5.66±0.25	5.96±0.38	5.50±0.13	6.15±0.49
Water (%)	6.33±2.41					9.38±3.38	13.67±2.55	10.71±2.45	10.32±4.11	14.56±1.80
Org. Matter (%)	28.82±11.70					39.89±13.44	60.35±11.34	42.85±12.39	44.00±17.52	70.01±9.19
Carbon (%)	19.84±8.62						39.32±7.94	26.04±7.85	27.90±11.99	45.07±6.49
Nitrogen (%)	0.48±0.13						1.12±0.29	0.92±0.31	0.91±0.27	1.26±0.16
C/N ratio	41.76±14.60						37.22±14.61	30.30±9.57	29.70±6.02	36.19±7.22
Mineral horiz.										
pH	8.05±0.47	7.70±0.58	6.69±0.96	6.69±0.59	6.45±0.94	7.25±0.43	6.10±0.29	6.16±0.23	6.07±0.21	6.24±0.28
Water (%)	2.43±0.84	7.70±3.98	0.72±0.43	0.98±0.62	2.55±1.34	5.96±2.82	7.49±1.72	5.97±0.68	6.78±2.29	8.31±3.08
Org. Matter (%)	8.13±3.22	9.15±7.07	2.06±1.28	4.22±2.97	6.12±2.40	17.07±8.94	26.47±6.30	17.00±2.80	23.69±7.79	31.75±10.69
Carbon (%)	6.11±2.58	3.33±2.63	0.90±0.49	2.21±1.7	2.10±0.82	6.52±3.70	14.60±4.96	8.95±1.54	12.27±3.65	21.25±9.62
Nitrogen (%)	0.27±0.09	0.25±0.19	0.08±0.05	0.12±0.07	0.22±0.09	0.42±0.16	0.61±0.2	0.38±0.08	0.73±0.20	0.6±0.26
C/N ratio	22.16±4.76	10.87±1.93	13.59±7.30	17.77±3.53	9.55±1.81	15.17±4.09	24.31±5.10	24.51±5.78	16.74±1.64	30.39±4.53

NOTE: Number of samples per biotope as in Table II

during both sampling periods are due either to the low number of taxa (C. Marim 95) or to low evenness (C. Marim 96). Inside Serra de Monchique, the diversity in Eucalyptus III seems not to fit the general pattern, *e.g.* lower diversity for the allochthonous biotopes. The reason for this is related to the increase in evenness (when compared to the other eucalyptus sites) and not to a difference in species number. In general, the diversity values in all sites seem to be more influenced by the distribution of individuals among the different taxa rather than by species number.

A parallel between species diversity and species richness values is not so linear. Richness is strongly dependent on the number of taxa which in turn is related to the number of samples taken. However, with the exception of Sagres, and the eucalyptus sites in Serra de Monchique, the highest species richness occurred also in the inland biotopes.

Correspondence Analysis (CA; *fig.* 2) defined three groups. The first group includes all Serra de Monchique biotopes; axis 2 separates Eucalyptus I and Eucalyptus II from Eucalyptus III, which is more closely related to the other biotopes, especially to Q. canariensis and Rhododendron. This fact may be explained by the relative abundance of *Ceratophysella gibbosa* and *Pseudachorudina bougisi* in these three sites and of *Proisotoma minuta* in Eucalyptus III and Quercus canariensis. The association between Eucalyptus I and Eucalyptus II may be related mainly to the high abundance of *Xenylla brevisimilis mediterranea* in these stands (see Annex).

The second group includes Pinewoods I and II, Sagres, Barrocal 94 and 96 and Castro Marim 96, which is separated from the third group (the 'wet' coastal habitats: C. Marim 95, Salt-marshes and Dunes) by axis 2. The second and third groups are separated from the Serra de Monchique by axis 1.

In the second group, there is an association among the Pinewood, Sagres and Barrocal 94 and 96 sites. The great abundance of *X. brevisimilis mediterranea* in Sagres, Barrocal 94 and Barrocal 96, may explain the similarity among these sites. However, the degree of proximity between Sagres and Barrocal 94 is higher than between Sagres and Barrocal 96, which could be mainly due to the greater presence of *Cryptopygus debilis* in the first two sites (see Annex).

The position of C. Marim 96 together with these 'dry' biotopes could be attributed to the exclusive presence of *Hypogastrura affinis* in C. Marim 96 and Barrocal 96 and to the significant abundance of *Proisotoma minuta* in these two sites. Also the frequency of *Cryptopygus thermophilus* in these two sites and in Barrocal 94 may contribute to bring these biotopes together (see Annex).

The species diagram of the Correspondence Analysis also discriminates taxa associated to sites (*fig.* 3). On the right side of the first axis are the most representative taxa associated with the biotopes from Serra de Monchique. Five subgroups can be discriminated:

• The first subgroup (designated General) is composed mainly of those taxa that are also well represented in other biotopes, showing either: (1) higher abundance: *Pseudachorudina bougisi, Isotomiella minor, Parisotoma notabilis* and *Heteromurus major* (in Barrocal 1996) and *Cryptopygus debilis* (in Pinewood II, Sagres and Barrocal 1994)[2]; or (2) the same degree of abundance (*Ceratophysella gibbosa, Sphaeridia pumilis* and *Xenylla brevisimilis mediterranea*). *Cryptopygus debilis* was not yet referred to Portugal (*table* 4).

• The second subgroup (designated by Quercus sites + Rhododendron) is represented by taxa that occur mainly on these biotopes, being very sporadic in a few biotopes out of Serra de Monchique. *Deutonura atlantica*, an endemic to Portugal and the Iberian endemic *Lepidocyrtus lusitanicus* (*table* 3) are important species in this group. *Friesea decipiens, Folsomides navacerradensis*

2. It is important to note that the presence of this species, characteristic of mountain beech forest from Pyrenees, in several sites of Algarve remains a puzzling question.

Table 2. – Abundance of Collembola species in the five areas studied. Diversity indicators for all biotopes shown.

		Serra de Monchique									Ria Formosa					
Taxa	Sagres	Rhod.	Q.can.	Q.suber I	Q.suber II	Euc. I	Euc. II	Euc. III	Barr. 94	Barr. 96	Salt-marshes	Dunes	Pine I	Pine II	C.Mar. 95	C.Mar. 96
Number of samples	20	7	8	5	4	4	4	4	9	20	9	10	5	3	29	22
Total abundance	1763	3529	2056	2106	1997	865	1902	486	1799	8865	188	1499	966	522	218	1442
Number of Taxa	57	45	46	41	37	21	23	25	30	49	20	29	29	27	13	31
Average abundance	88.15	504.14	257,0	421.2	499.25	216.25	475.5	121.5	199.89	443.25	20.89	149.9	193.2	174,0	7.52	65.55
Average number of Taxa	9.5	22.14	16.25	21,0	21.5	9.5	10.75	14.75	9.44	14.95	4.56	5.1	11.8	13.67	1.31	4.545
Diversity (H')	3.27	2.56	3.48	2.66	2.68	1.73	1.69	3.45	3.22	2.57	3.25	3.25	3.03	3.46	2.58	2.65
Evenness	0.56	0.47	0.63	0.49	0.52	0.39	0.38	0.74	0.66	0.46	0.75	0.67	0.62	0.73	0.69	0.53
Richness (D)	7.49	5.39	5.89	5.23	4.74	2.96	2.91	3.88	3.87	5.28	3.63	3.83	4.07	4.16	2.23	4.12

NOTE: Each sample corresponds to 500cm³ of soil. So, number of individuals per 500cm³ is indicated as average abundance.

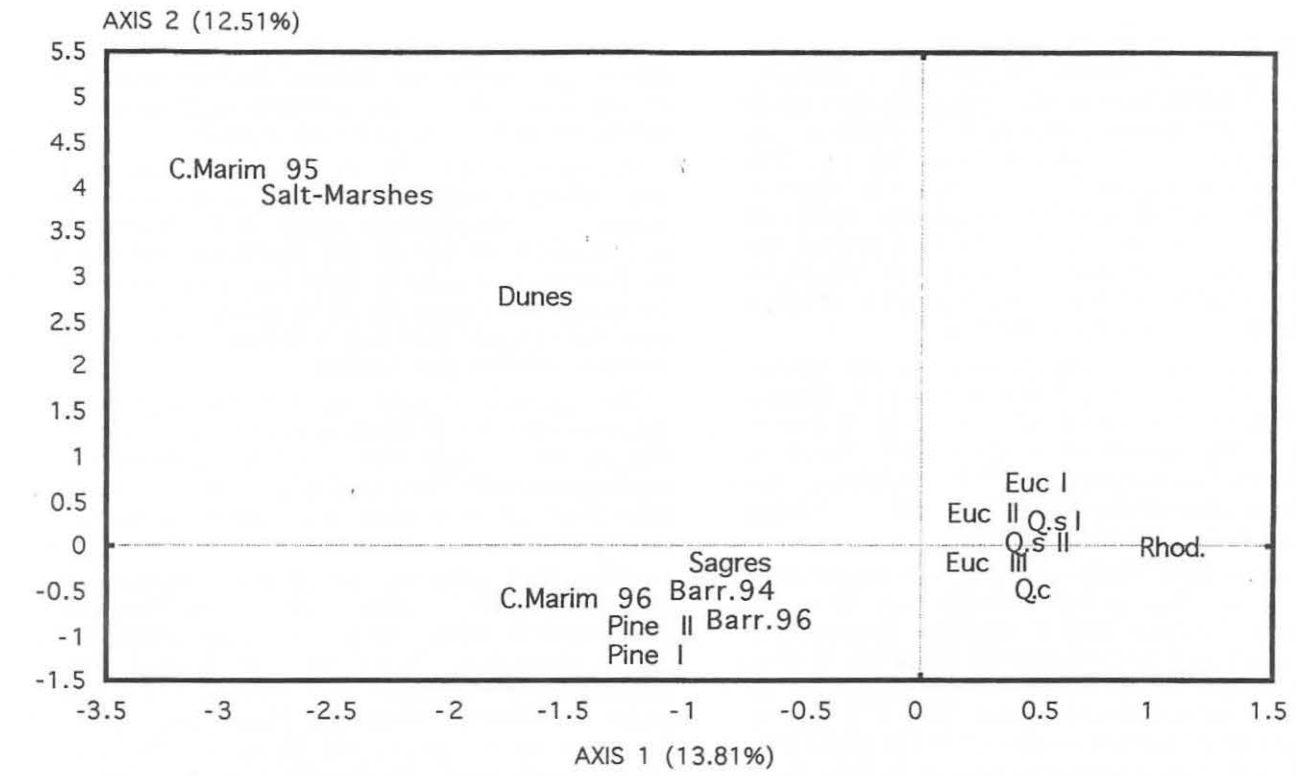

Figure 2. – Projection of the study sites in the 1-2 factorial plan of the correspondence analysis performed with the overall data matrix. χ^2 distances were calculated over average abundances.

Table 3. – Portuguese or Iberian endemic species from High Endemism Areas (HEA) in Algarve.

Portuguese endemics	
Deutonura atlantica	Deharveng, 1982
Mesaphorura	sp.2
Mesaphorura	sp.3
Proisotoma coeca	Gama, 1961
Proisotoma gisini	Gama, 1964
Pseudosinella	sp.
Troglopedetes cavernicola	Delamare, 1944
Willowsia	sp.
Iberian endemics	
Microgastrura sensiliata	Jordana, 1981
Gamachorutes verrucosus	Cassagnau, 1978
Mesaphorura arbeai	Simón & Lucianez, 1994
Mesaphorura florae	Simón & Lucianez, 1994
Mesaphorura	sp.1
Lepidocyrtus lusitanicus	Gama, 1964
Lepidocyrtus tellecheae	Arbea & Jordana, 1990

Table 4. – Species from High Endemism Areas (HEA) in Algarve referred to Portugal or to the Iberian Peninsula for the first time.

1st citation for Portugal	
Friesea decipiens	Steiner, 1958
Odontellina bisetosa	Selga, 1963
Microgastrura minutissima	Mills, 1934
Protaphorura fimata	Gisin, 1952
Fissuraphorura gisini	Selga, 1963
Mesaphorura critica	Ellis, 1976
Mesaphorura florae	Simón & Luciáñez, 1994
Mesaphorura hylophila	Rusek, 1982
Metaphorura denisi	Simón, 1985
Scaphaphorura arenaria	Petersen, 1965
Archisotoma interstitialis	Delamare, 1954
Cryptopygus debilis	Cassagnau, 1959
Cryptopygus ponticus	Stach, 1947
Folsomides navacerradensis	Selga, 1962
Folsomides xerophilus	Fjellberg, 1993
Folsomides pocosensillatus	Fjellberg, 1993
Entomobrya handschini	Stach, 1922
Lepidocyrtus tellecheae	Arbea & Jordana, 1990
Arrhopalites microphthalmus	Cassagnau & Delamare, 1953
Stenognathellus denisi	Cassagnau, 1953
1st citation for the Iberian Peninsula	
Friesea acuminata	Denis, 1925
Friesea stachi	Kseneman, 1936
Onychiurus penetrans	Gisin, 1952

and *Stenognathellus denisi* were recorded for the first time to Portugal (*table* 4).

• The seven species which compose the third subgroup appear in Eucalyptus sites, but are also represented in Quercus and very rarely in other

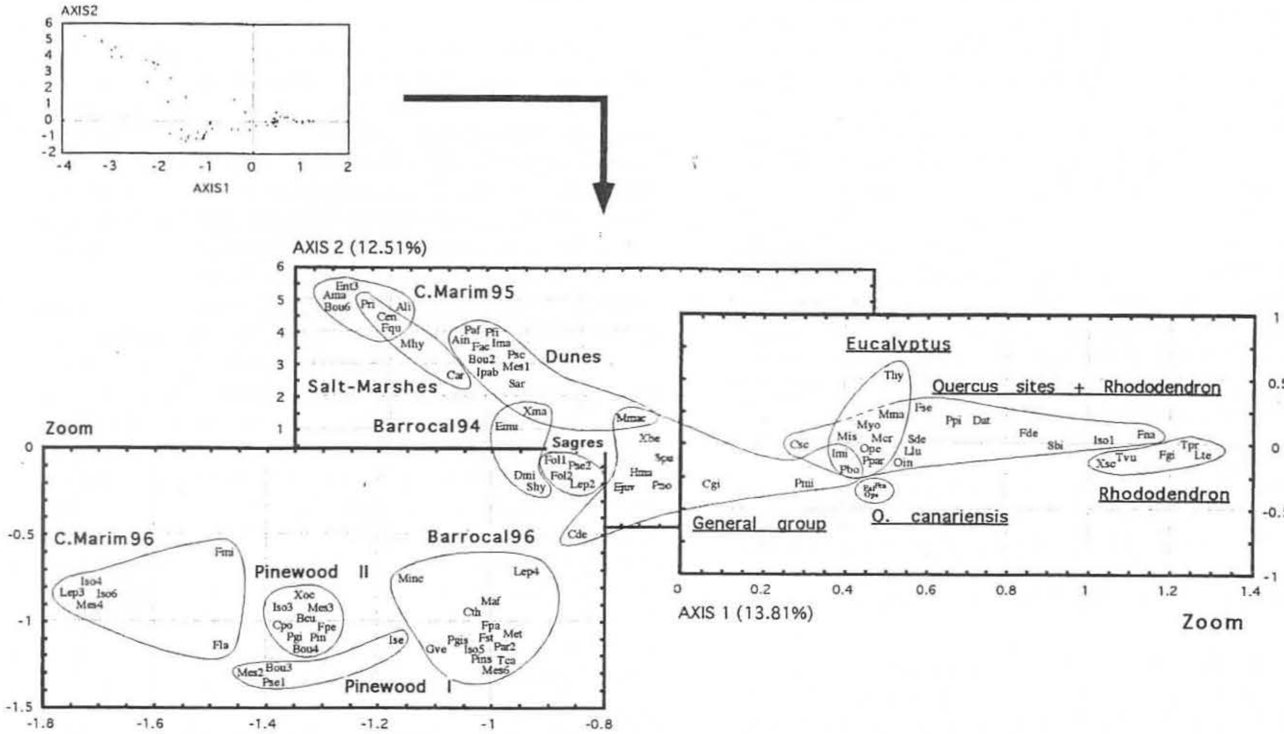

Figure 3. – Projection of the most representative taxa in the 1-2 factorial plan of the correspondence analysis performed with the overall data matrix. χ^2 distances were calculated over average abundances. Underlined names correspond to subgroups from the Serra de Monchique area, resulting from the correspondence analysis (in some cases subgroup names may be similar to biotope names).

biotopes. Among these species, *Pseudachorutes parvulus, Mesaphorura* sp. 3, *Mesaphorura critica, Mesaphorura* sp. 2 and *Mesaphorura yosii* are dominant in Eucalyptus III. *Onychiurus penetrans,* found for the first time in Portugal, as well as *M. critica,* is exclusive to this site. *Mesaphorura* sp. 2 and *Mesaphorura* sp. 3 are probably endemic to Portugal. *Proisotoma coeca* (not represented in the CA diagram) is endemic to Portugal and is exclusive of Eucalyptus I. *Mesaphorura arbeai* (not indicated in the CA diagram), present mainly in Eucalyptus II and Quercus, is an Iberian endemic. *Microgastrura sensillata* is also an Iberian endemic which occurred mainly in Eucalyptus III and in Quercus sites (*table* 3).

• The taxa of the fourth subgroup show a marked preference for Rhododendron, *Tetracanthella proxima* being the most abundant species, represented here by 2025 individuals. *Lepidocyrtus paradoxus, Willowsia* sp., *Pogonognathellus flavescens* (not indicated in the CA diagram) and the Iberian endemic *Lepidocyrtus tellecheae* are exclusive of this biotope. *Xenylla schillei, Fissuraphorura gisini* and *Tomocerus vulgaris* (also included in this subgroup) are equally represented in Q. canariensis but in low numbers. *Fissuraphorura gisini* and *Lepidocyrtus tellecheae* are reported for the first time to Portuguese fauna (*table* 4); this recently described species, has a distribution ranging from Navarra to the Algarve.

• The fifth subgroup of Serra de Monchique includes some species, from which *Onychiurus pseudostachianus, Entomobrya albocincta, Cryptopygus sphagneticola, Lepidocyrtus lanuginosus* and *Pseudosinella* sp. appear exclusively in Q. canariensis site (the last three species are not represented in the CA diagram). *Folsomia candida* is the dominant species with 581 individuals.

On the left side of the species CA diagram (*fig.* 3) the second axis separates the 'wet' biotopes in the upper corner (C. Marim 95, Salt-Marshes and Dunes) from the 'dry' coastal and inland sites in the lower corner (Sagres, Barrocal 94 and 96, Pinewoods I and II and C. Marim 96).

In this last group, among the species occurring in Sagres, *Folsomides pocosensillatus, F. xerophilus, Mesaphorura florae, Mesaphorura* sp. 1 (two Iberian endemic; *table* 3), *Entomobrya handschini* and *Arrhopalites microphthalmus* are for the first time recorded to Portuguese fauna (*table* 4) (the last four species are not represented in the CA diagram).

In Barrocal 94, located in a coastal area (Carvoeiro, near Farol de Alfanzina), *Stenacidia hystrix* is, among the exclusive species of this site, an interesting and rare Mediterranean species. Barrocal 96, located inland (between Alte and Salir), includes 8 exclusive species; among them are *Metaphorura denisi*, the dominant species represented by 266 individuals, *Friesea stachi,*

Willowsia sp. (probably endemic, not indicated in the diagram) and *Troglopedetes* cf. *cavernicola*. This last species has a special interest because it is an endemic species previously found only in caves in the south of Portugal (*table* 3). *Metaphorura denisi* and *Microgastrura minutissima* (not represented in the diagram) are recorded for the first time to Portugal and *Friesea stachi* to the Iberian Peninsula. *Gamachorutes verrucosus*, also found in Pinewood I, is a very interesting Iberian endemic species, which appears for the first time since its original description in 1978, based on individuals from Algarve, Malaga and Cordoba. On a preliminary sampling, carried out in this site in 1994 (not included in this study), we found the species *Odontellina bisetosa*, an Iberian species found for the first time in our fauna.

The majority of taxa found in Pinewood II are exclusive of this biotope. *Cryptopygus ponticus* is referred for the first time to Portugal (*table* 4) and *Proisotoma gisini* is an endemic species to Portugal (*table* 3). Pinewood I also presents some exclusive species, but not as interesting as Pinewood II (see Annex).

Most of the taxa occurring in salt-marshes of C. Marim 96 are not characteristic of this biotope. In fact, in the CA diagram, this biotope is associated with the 'dry' biotopes rather than the 'wet' coastal habitats in the upper left corner (*fig.* 3). This may be explained by the rich and diverse vegetation cover in Spring 1996 during the sampling period, leading to the appearance of species not characteristic of this biotope. Among these taxa is a new species of *Pseudosinella* (Pse 3, not represented in the diagram), probably endemic to Algarve (*table* 3) and *Friesea ladeiroi* (also found in Pinewood I and Barrocal 94), known only from continental Portugal and Madeira Island.

From the 'wet' coastal biotopes, we highlight the species *Anurida maritima, Bourletiella* sp., *Entomobrya* sp. and *Axelsonia littoralis* exclusive for C. Marim 95; the last species appears also in dunes in low abundance. Among the species from salt-marshes is *Proisotoma ripicola* which occurs normally in sandy soils near water margins and *Mesaphorura hylophila*, also found in Sagres, here cited for the first time in Portugal (*table* 4). Most of the species occurring in Sand dunes biotope are characteristic of littoral and lagoon-side habitats: *Archisotoma interstitialis* (also found in C. Marim 95), *Friesea acuminata* (also found in Salt-marshes), *Scaphaphorura arenaria* (also found in Sagres), *Paraxenylla affiniformis, Proisotoma schoetti* (also found in Salt-marshes and C. Marim 96), *Isotoma maritima meridionalis* and *Sminthurides malmgreni* (not figured in the diagram). The first three species are for the first time cited to Portugal in addition to *Protaphorura fimata*, exclusive to this site (*table* 4). The presence of *Paraxenylla affiniformis* here and in C. Marim 95 increases the distribution area of this species which some years ago was restricted to the Balkans.

DISCUSSION

The overall data analysis shows a separation of three groups of sites among the studied areas: the biotopes of Serra de Monchique, coastal 'wet' biotopes (Salt-marshes and Dunes) and the other 'dry' coastal or inland sites (Sagres, Pinewood and Barrocal sites). The only site which seems not to fit is C. Marim 96; this biotope appears not to be associated with coastal sites, but is included in the group composed of Sagres, Pinewood sites and both Barrocal biotopes. This fact may be explained by the rich and diverse vegetation cover in Spring 1996, when sampling was carried out.

This separation of different faunal spectra, and its relation to the different habitat types, enhances the importance of these areas in terms of biodiversity conservation. The number of new species (*table* 4) and the number of rare or endemic species (*table* 3) helps in this aim. In fact, all the studied biotopes had species endemic to Portugal or to the Iberian Peninsula; among them, we emphasize species such as *Deutonura atlantica, Lepidocyrtus lusitanicus* and L. *tellecheae* occurring in Serra de Monchique, or even *Troglopedetes cavernicola*, which appeared exclusively in Barrocal 96; this last species is of special interest because, according to Deharveng (pers. comm.), it must be considered as a paleoendemic species dating from warmer periods of the Tertiary. Another interesting species is the Iberian endemic *Gamachorutes verrucosus*, almost exclusive to Barrocal 96.

Among other species cited for the first time in Portugal or the Iberian Peninsula, some are characteristic of littoral and lagoon-side habitats (*Archisotoma interstitialis* found in Dunes of Ria Formosa and in C. Marim 95, *Friesea acuminata* in Dunes and Salt-marshes, and *Scaphaphorura arenaria* in Dunes and Sagres) and other interesting species like *Cryptopygus debilis*, considered until now endemic to beech forest from the French Pyrenees (Deharveng, 1996), but present in almost all biotopes in the Algarve. We also recorded the presence of *Folsomides xerophilus* and *F. pocosensillatus*, two species described recently from Canary Islands (Fjellberg, 1993) and *Fissuraphorura gisini* known from Spain and Canary Islands until now.

Each study site supports a great variety of Collembola species and also interesting species from other invertebrate groups and plants. However, we would like to highlight the Serra de Monchique area, particularly those biotopes dominated by *Rhododendron ponticum baeticum*, a relictual endemic shrub, occurring in Portugal only in this mountain and in the mountain of Caramulo, and also the biotope dominated by *Quercus canariensis*, which equally presents a very restricted occurrence both in Portugal and in Spain, Serra de Monchique being its exclusive area (Rocha Afonso, 1991). In terms [illegible] diversity and species richnes[illegible]re in general presented by these two biotopes. The great number of

Collembola endemic species (*table* 3) present in this 'continental island' reinforces this position.

All five areas are constantly being threatened by several stress factors such as reafforestation with exotic species (Eucalyptus is a critical problem in Serra de Monchique), forest fires and by uncontrolled touristic development (a serious threat in coastal areas). In face of this situation, well established conservation plans are needed to avoid habitat degradation and local loss of biological diversity. It makes no sense to preserve habitats without protecting those species living there. Often regarded as different perspectives, habitat and species conservation must be requirements acting mutually in a well balanced conservation plan.

Reinforcing the idea that endemic or rare biota represent, from a conservation perspective, the most valuable and vulnerable element of the fauna implies that high endemism areas should therefore be considered a priority for conservation (Deharveng, 1996). It is our aim to make the data from this study available both to the scientific community and to the competent authorities dealing with nature conservation in Portugal. Recommendations will be made to preserve or restore the biological richness of these areas, encouraging the adoption of protective measures and the creation of research plans without neglecting the necessity to continue their systematic inventory.

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Annex. – Abundance of Collembola species (total number of individuals extracted from all samples) in the five areas studied.

			Serra de Monchique									Ria Formosa					
	Taxa	Sagres	Rhod.	Q.can.	Q.suber I	Q.suber II	Euc. I	Euc. II	Euc. III	Barr. 94	Barr. 96	Salt-marshes	Dunes	Pine I	Pine II	C.Mar. 95	C.Mar. 96
Car	*Ceratophysella armata* Nicolet, 1841	9									15	24	10	4	1		
Cen	*Ceratophysella engadinensis* Gisin, 1949	4										11				8	
Cgi	*Ceratophysella gibbosa* Bagnall, 1940	23	71	90	62	57	2	2	70	62	31			94	1		
Cte	*Ceratophysella tergilobata* Cassagnau, 1954											1					
Cte	*Hypogastrura affinis* Cassagnau, 1954										12						11
Hve	*Hypogastrura vernalis* Carl, 1901									4							
Mmi	*Microgastrura minutissima* Mills, 1934	1	3								14						
Mse	*Microgastrura sensiliata* Jordana, 1981				6	1			5				1				
Mic1	*Microgastrura* juv. (Salt-marshes)											4					
Mic2	*Microgastrura* juv. (Pinewood I)													5			
Paf	*Paraxenylla affiniformis* Stach, 1929												96			16	
Win	*Willemia intermedia* Mills, 1934		1						1								
Xbe	*Xenylla brevisimilis mediterranea* Gama, 1964	339	1		58	1	249	496		430	463		350		1		
Xma	*Xenylla maritima* Tullberg, 1869	8								137			130			4	2
Xsc	*Xenylla schillei* Börner, 1903		4	2													
Xar	*Xenyllodes armatus* Axelson, 1903														1		
Xoc	*Xenyllogastrura octoculata* Steiner, 1955	3								162			38	411	70		7
Bcu	*Brachystomella curvula* Gisin, 1948														10		
Bpa	*Brachystomella parvula* Schäffer, 1896													5			6
Ama	*Anurida maritima* Guerin, 1838															4	
Bau	*Bilobella aurantiaca* Caroli, 1912	1	2	2	8	3	3	5	4		123			6	5		
Dat	*Deutonura atlantica* Deharveng, 1982		25	4	11	7	8	9	4								
Fac	*Friesea acuminata* Denis, 1925											3	30				
Fde	*Friesea decipiens* Steiner, 1958		80	6		59	1										
Fla	*Friesea ladeiroi* Gama, 1959									1				16			31
Fmi	*Friesea mirabilis* Tullberg, 1871									17	1		1				101
Fst	*Friesea stachi* Kseneman, 1936										15						
Gve	*Gamachorutes verrucosus* Cassagnau, 1978										13			1			
Micr1	*Micranurida* (2+2 eyes) sp.1	9	1		12	13		3	9		2	9	1				
Micr2	*Micranurida* (2+2 eyes) sp. 2											4					
Nea	*Neanura* sp. (Q.suber I)				3												
Pbo	*Pseudachorudina bougisi* Delamare, 1951	3	270	290	56	63	1	45	85	80	349			1	5		1
Ppal	*Pseudachorutes palmiensis* Börner, 1903	1		1				1	2		24						
Ppar	*Pseudachorutes parvulus* Börner, 1901	2	1						11								
Psu	*Pseudachorutes subcrassus* Tullberg, 1871			1	5						35						
Pse1	*Pseudachorutes* sp. (Pinewood I)													36			
Pse2	*Pseudachorutes* sp. (Sagres)	19															
Pse3	*Pseudachorutes* sp. (Barrocal 96)										9						
Fgi	*Fissuraphorura gisini* Selga, 1963		7	1													
Mar	*Mesaphorura arbeai* Simón & Luciáñez, 1994			1	6	6		12					1				
Mco	*Mesaphorura* sp. 1	5				1	1	1	1								
Mcr	*Mesaphorura critica* Ellis, 1976					1		1	8								
Mfl	*Mesaphorura florae* Simón & Luciáñez, 1994	2														1	
Mhy	*Mesaphorura hylophila* Rusek, 1982	2										4					
Mis	*Mesaphorura* sp. 2	2		1	1	1	1	1	23								
Mkr	*Mesaphorura krausbaueri* Börner, 1901	1															
Mma	*Mesaphorura* sp. 3	8	1	1	4	4	2	8	11								
Mmac	*Mesaphorura macrochaeta* Rusek, 1976	4	11	13	6	11	1		16				70				
Myo	*Mesaphorura yosii* Rusek, 1967	1		2	2		7		11								
Mes1	*Mesaphorura* sp. (Dunes)												24				
Mes2	*Mesaphorura* sp. (Pinewood I)													40			
Mes3	*Mesaphorura* sp. (Pinewood II)														34		
Mes4	*Mesaphorura* sp. (C. Marim 96)																195
Mes5	*Mesaphorura* sp. (Barrocal 94)									1							
Mes6	*Mesaphorura* sp. (Barrocal 96)										222						
Maf	*Metaphorura affinis* Börner, 1903									9	53				1		
Met	*Metaphorura denisi* Simón, 1985										266						
Oci	*Onychiurus circulans* Gisin, 1952					1											
Oin	*Onychiurus insinuans* Gisin, 1952			52	11	8											
Ope	*Onychiurus penetrans* Gisin, 1952								16								
Ops	*Onychiurus pseudostachianus* Gisin, 1956			25													
Pca	*Paratullbergia callipygos* Börner, 1903	1	2	3		3			2								
Par1	*Protaphorura armata* Tullberg, 1869						4	5		5	5						1
Par2	*Protaphorura* gr. *armata*										19						
Pfi	*Protaphorura fimata* Gisin, 1952												68				
Pgis	*Protaphorura gisini* Haybach, 1960										44				1		
Sar	*Scaphaphorura arenaria* Petersen, 1965	13											22				
Squ	*Stenaphorura quadrispina* Börner, 1901	2															

Annex. – (cont. 1).

			Serra de Monchique									Ria Formosa					
	Taxa	Sagres	Rhod.	Q.can.	Q.suber I	Q.suber II	Euc. I	Euc. II	Euc. III	Barr. 94	Barr. 96	Salt-marshes	Dunes	Pine I	Pine II	C.Mar. 95	C.Mar. 96
Ain	*Archisotoma interstitialis* Delamare, 1954												54			31	
Ali	*Axelsonia littoralis* Moniez, 1890												1			4	
Cde	*Cryptopygus debilis* Cassagnau, 1959	745	23	1		63		2		215	2				167		1
Cpo	*Cryptopygus ponticus* Stach, 1947														6		
Csc	*Cryptopygus scapelliferus* Gisin, 1955	1	14	26	27	227	1		16			3		53		2	
Csp	*Cryptopygus sphagneticola* Axelson, 1912			3													
Cth	*Cryptopygus thermophilus* Axelson, 1900	42	7	2		45	1	1		391	5321	3	1	133	16		729
Fca	*Folsomia candida* Willem, 1902		6	581													
Fqu	*Folsomia quadrioculata* Tullberg, 1871	4									2	55		2	4	97	1
Fse	*Folsomia sexoculata* Tullberg, 1871	33	416	134	1233	1131	502	1136	45					2			
Fna	*Folsomides navacerradensis* Selga, 1962		19		3												
Fpa	*Folsomides parvulus* Stach, 1922	5									80						1
Fpe	*Folsomides petiti* Delamare, 1951														33		
Fol1	*Folsomides xerophilus* Fjellberg, 1993	97								3			1				
Fol2	*Folsomides pocosensillatus* Fjellberg, 1993	39															
Ima	*Isotoma maritima meridionalis* Altner, 1963												50				
Imi	*Isotomiella minor* Schäffer, 1896	6	177	156	152	76	12	151	5		518						2
Ibi	*Isotomodes bisetosus* Cassagnau, 1959	3												6			
Ipr	*Isotomodes productus* Axelson, 1906									6							
Itr	*Isotomodes trisetosus* Denis, 1923 28?	7									40		7				10
Ise	*Isotomodes sexsetosus* Gama, 1963			7	3									46	5		
Ifu	*Isotomurus fucicolus* Reuter, 1891	12								6							
Ipab	*Isotomurus palustris bimaculatus* Müller, 1776	2										39	442				102
Iso1	*Isotomurus* sp. (Monchique)		68	10	5	10											
Iso2	*Isotomurus* juv. (Pinewood I)													1			
Iso3	*Isotomurus* juv. (Pinewood II)														24		
Iso4	*Isotomurus* sp. (C. Marim 96)																43
Iso5	*Isotomurus* sp. (Barrocal 96)										42						
Iso6	*Isotomurus* juv. (C. Marim 96)																69
Pno	*Parisotoma notabilis* Schäffer, 1896		10	233	1	33	2	4	1	1	487					2	
Pco	*Proisotoma coeca* Gama, 1961						2										
Pgi	*Proisotoma gisini* Gama, 1964														8		
Pmi	*Proisotoma minuta* Tullberg, 1871		3	249	8	35	1		130		72						80
Pri	*Proisotoma ripicola* Axelson, 1912											14					
Psc	*Proisotoma schoetti* Dalla Torre, 1895											1	67				1
Thy	*Tetracanthella hygropetrica* Cassagnau, 1954				1	1	57										
Tpi	*Tetracanthella pilosa* Schött, 1891												3				
Tpr	*Tetracanthella proxima* Steiner, 1955		2025	1	15			7	1	1				2			
Eal	*Entomobrya albocincta* Templeton, 1835			5													
Eat	*Entomobrya atrocincta* Schött, 1896																4
Eha	*Entomobrya handschini* Stach, 1922	5									1						
Emu	*Entomobrya multifasciata* Tullberg, 1871	15								11	5			1	1	36	8
Ent1	*Entomobrya* sp. (Monchique)		1		1			1									
Ent2	*Entomobrya* sp. (Sagres)	8															
Ent3	*Entomobrya* sp. (C. Marim 95)															8	
Ent4	*Entomobrya* sp. (C. Marim 96)																5
Hma	*Heteromurus major* Moniez, 1889	19	52	12	67	40		2			358			7	56		5
Lla	*Lepidocyrtus lanuginosus* Gmelin, 1788			1													
Llu	*Lepidocyrtus lusitanicus* Gama, 1964		1	29	9	8		1					1				
Lpa	*Lepidocyrtus paradoxus* Uzel, 1890		2														
Lte	*Lepidocyrtus tellecheae* Arbea & Jordana, 1990		8														
Lep1	*Lepidocyrtus* sp. (Pinewwod I)													2			
Lep2	*Lepidocyrtus* sp. (Sagres)	76															
Lep3	*Lepidocyrtus* sp. (C. Marim 96)																14
Lep4	*Lepidocyrtus* sp. (Barrocal 94 and 96)									9	24						
Pin	*Pseudosinella infrequens* Gisin & Gama. 1969														5		
Pim	*Pseudosinella imparipunctata* Gisin, 1953	1															
Pins	*Pseudosinella insularum* Dallai, 1969										26						
Ppi	*Pseudosinella picta* Börner, 1903		28	8	96	8	7	8	6	1							1
Pse6	*Pseudosinella* sp. (0+0 eyes) (Q. canariensis)			1													
Pse4	*Pseudosinella* sp. (0+0 eyes) (Sagres)	3															
Pse3	*Pseudosinella* sp. (0+0 eyes) (C. Marim 96)																2
Sco	*Sinella coeca* Schött, 1896													1			
Wil1	*Willowsia* sp. (Rhododendron)		2														
Wil2	*Willowsia* sp. (Barrocal 96)										3						
Ejuv	*Entomobryidae* juv.	50	36	24	19	1					59	4	1	37	14		

Annex. – (cont. 2).

			Serra de Monchique									Ria Formosa					
	Taxa	Sagres	Rhod.	Q.can.	Q.suber I	Q.suber II	Euc. I	Euc. II	Euc. III	Barr. 94	Barr. 96	Salt-marshes	Dunes	Pine I	Pine II	C.Mar. 95	C.Mar. 96
Ocr	*Oncopodura crassicornis* Shoebotham, 1911		2	1							7						
Tca	*Troglopedetes* cf. *cavernicola* Delamare, 1944										13						
Pfl	*Pogonognathellus flavescens* Tullberg, 1871		2														
Tvu	*Tomocerus vulgaris* Tullberg, 1871		7	3													
Minc	*Megalothorax incertus* Börner, 1903	7								2	32	1		3			
Mmin	*Megalothorax minimus* Willem, 1900	8	13	11	47	7			3	5	3						
Nmu	*Neelus murinus* Folsom, 1896			3	3							1					
Afus	*Allacma fusca* Linnaeus, 1758				1												
Aca	*Arrhopalites caecus* Tullberg, 1871	1															
Ael	*Arrhopalites elegans* Cassagnau & Delamare, 1953					2											
Afu	*Arrhopalites furcatus* Stach, 1945	3	3								3						
Ami	*Arrhopalites microphthalmus* Cassagnau & Delamare, 1953	2															
Arr1	*Arrhopalites* juv. (Monchique)			7	13												
Arr2	*Arrhopalites* sp. (Sagres)	6															
Bou1	*Bourletiella* sp. (Salt-marshes)											2					
Bou2	*Bourletiella* sp. (Dunes)												13				
Bou3	*Bourletiella* sp. (Pinewood I)													36			
Bou4	*Bourletiella* sp. (Pinewood II)														31		
Bou5	*Bourletiella* sp. (Sagres)	2															
Bou6	*Bourletiella* sp. (C. Marim 95)															5	
Bou7	*Bourletiella* sp. 1 (C. Marim 96)																2
Bou8	*Bourletiella* sp. 2 (C. Marim 96)																1
Cbr	*Caprainea bremondi* Delamare & Bassot, 1957			3	2						1				1		
Dic	*Dicyrtoma* sp. (Barrocal 94)									2							
Dmi	*Dicyrtomina minuta* Linnaeus, 1767									31	3						
Dor	*Dicyrtomina ornata* Nicolet, 1841										4						
Llub	*Lipothrix lubbocki* Tullberg, 1872	1	19	3	2	14				11	1						
Sma	*Sminthurides malmgreni* Tullberg, 1876												3				
Spa	*Sminthurides parvulus* Krausbauer, 1898		13		7							2	1				
Sau	*Sminthurinus* cf. *aureus* Lubbock, 1862													5			
Sbi	*Sminthurinus bimaculatus* Axelson, 1902	6	46		10	1					12						
Sdo	*Sminthurinus domesticus* Gisin, 1963										1						
Sel	*Sminthurinus elegans* Fitch, 1863	1															
Smu	*Sminthurus* cf. *multipunctatus* Schäffer, 1896		1														
Smin1	*Sminthurus* sp. (C. Marim 96)																2
Smin2	*Sminthurus* sp. (Barrocal 94)									3							
Spu	*Sphaeridia pumilis* Krausbauer, 1898	45	9	34	127	39				184	19		12	6	8		4
Shy	*Stenacidia hystrix* Börner, 1903									4							
Sde	*Stenognathellus denisi* Cassagnau, 1953			4	1	5											
Sjuv	*Symphypleona* juv.	45	36	9	2	11				5	11	3		4	13		